Sixth Annual Conference on Carbon Capture & Sequestration

Carbon Capture and Geological Storage Analogues from Pennsylvania's Natural Gas Storage Fields

Karen Kluger Cohen[1]   Michael A. Trevits[2]

[1]U.S. Department of Energy, National Energy Technology Laboratory
[2]National Institute for Occupational Safety and Health, Pittsburgh Research Laboratory

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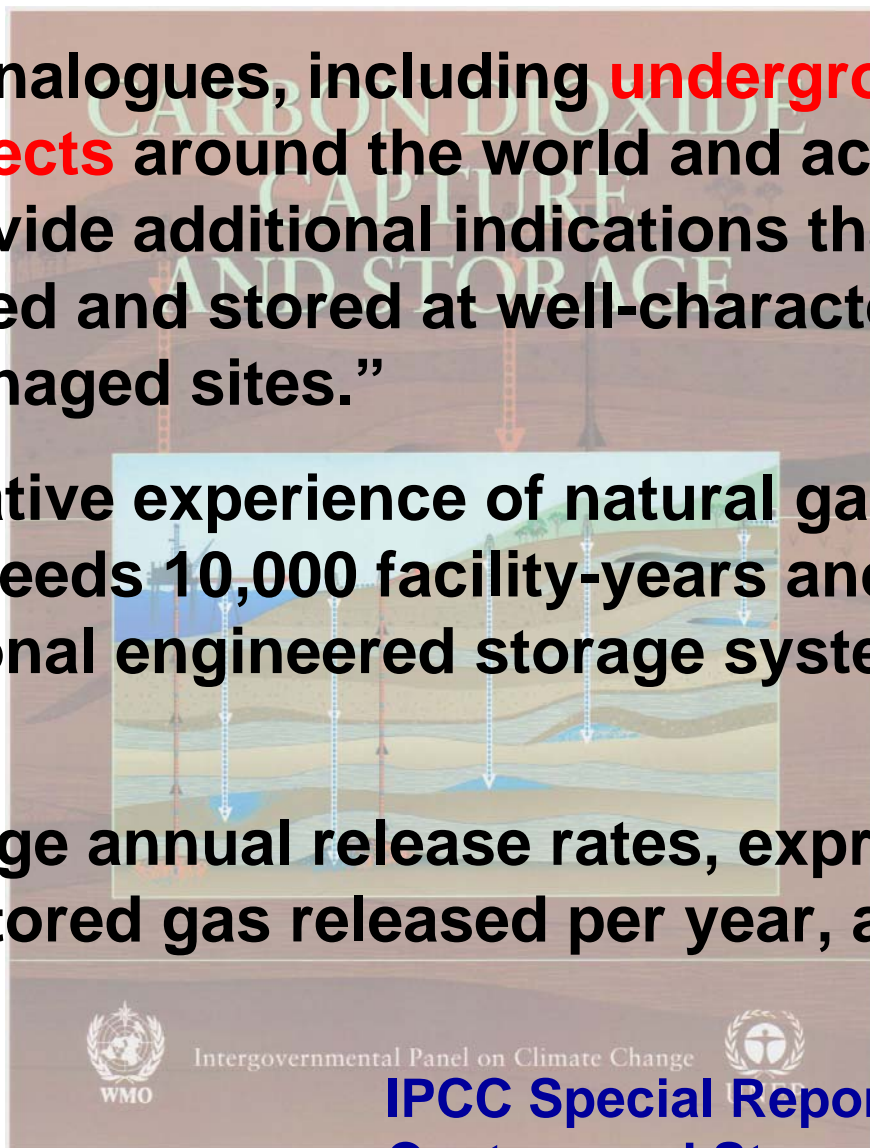# Carbon Capture and Geological Storage Analogues (CCGS) from Pennsylvania's Natural Gas Storage Fields

- **Importance and previous studies**

- **Background, PA oil and gas**

- **PA natural gas storage fields – settings, geology, surface/ underground facilities, operations, regulatory framework**

- **Relevance and synergy for CCGS**

Importance and Previous Studies

"**Industrial analogues, including underground natural gas storage projects around the world and acid gas injection projects provide additional indications that CO_2 can be safely injected and stored at well-characterized and properly managed sites.**"
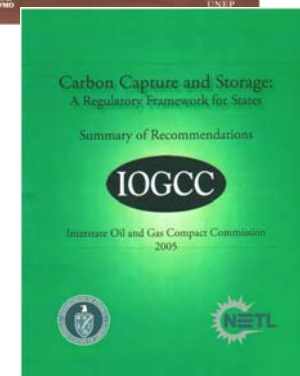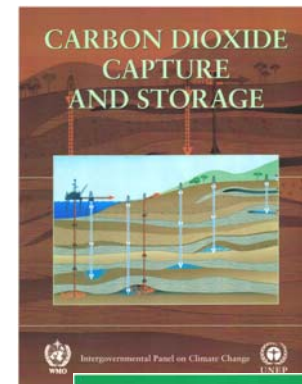
"**The cumulative experience of natural gas storage systems exceeds 10,000 facility-years and demonstrates that operational engineered storage systems can contain methane...**"

"**...the average annual release rates, expressed as a fraction of stored gas released per year, are likely below 10^{-5}.**"

IPCC Special Report on Carbon Dioxide Capture and Storage, 2005
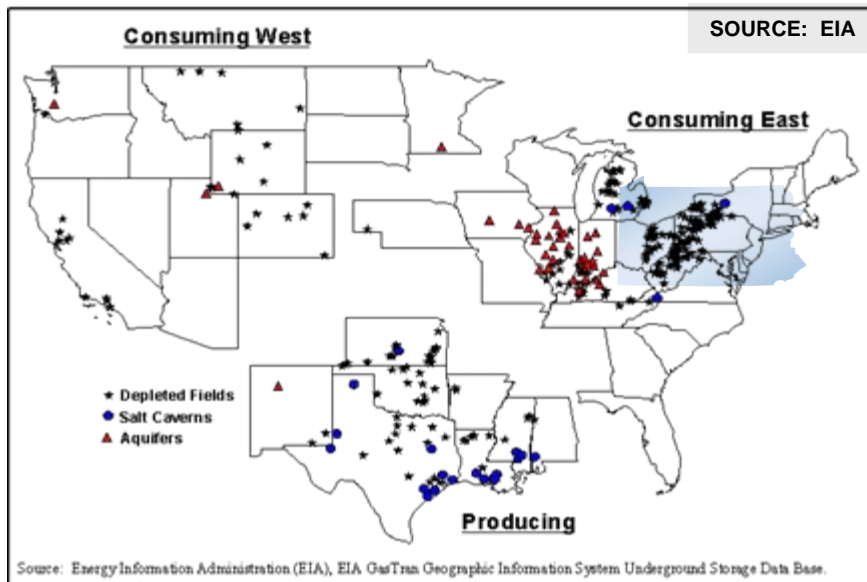
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Importance and Previous Studies

- **Analogue applications of natural gas storage fields recognized by experts**
  - IPCC 2005 Special Report
  - Interstate Oil and Gas Compact Commission 2005 Report; *"States and provinces with natural gas storage statutes should utilize their existing natural gas regulatory frameworks, with appropriate modifications, for CCGS."*

- **Regional CO_2 storage assessments and activity**
  - Hovorka, et al, Optimal Geological Environments for Carbon Dioxide Disposal in Brine Formations in the United States, DOE Contract DE-AC26-98FT40417
  - Midwest Carbon Sequestration Regional Partnership (MRCSP), DOE Coop. Agreements DE-FC26-03NT41981 and DE-FC26-05NT42589
  - PA DCNR, PA Carbon Management Advisory Group
  - Cambrian: Potsdam SS, Gatesburg Fm
    Silurian: Tuscarora-Medina-Keefer SS, Lockport dolomite
    Devonian: L. Dev. Oriskany SS, organic-rich shales, U. Dev. Bradford and Venango Gps
    Pennsylvanian-age coal seams

Background – U.S. Natural Gas Storage Facilities

Source: Energy Information Administration (EIA), EIA GasTran Geographic Information System Underground Storage Data Base.

- **Depleted reservoirs**
- **~ 65 fields**
- **Western PA Paleozoic oil-gas bearing sedimentary rocks**

"**The most common underground gas storage facilities are those that use deep underground natural gas or oil reservoirs that have been depleted through earlier production. These reservoirs are naturally occurring, and their potential as secure containers has been proven over the millenia…**"

FERC, Staff Report, 2004

"**…using an already developed reservoir for storage purposes allows the use of the extraction and distribution equipment left over from when the field was productive. Having this network in place reduces the cost of converting a depleted reservoir into a storage facility. Depleted reservoirs are also attractive because their geological characteristics are already well know. Of the three types of underground storage, depleted reservoirs, on average, are the cheapest and easiest to develop, operate and maintain.**"
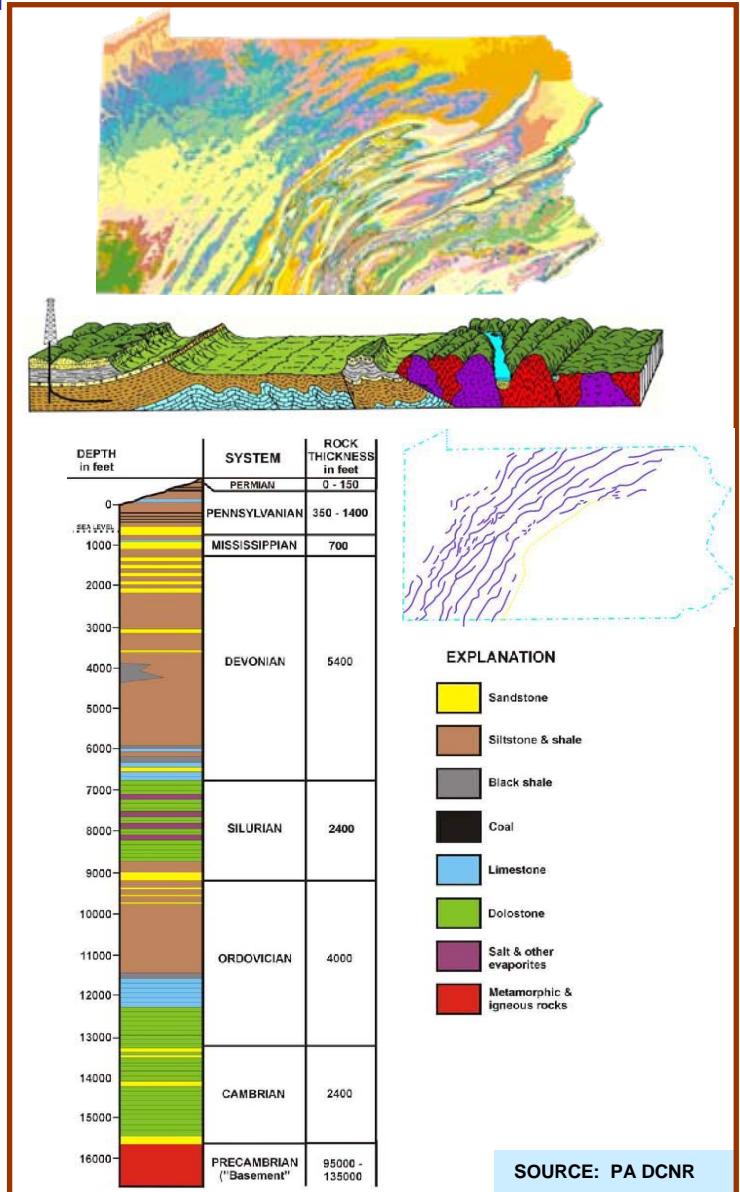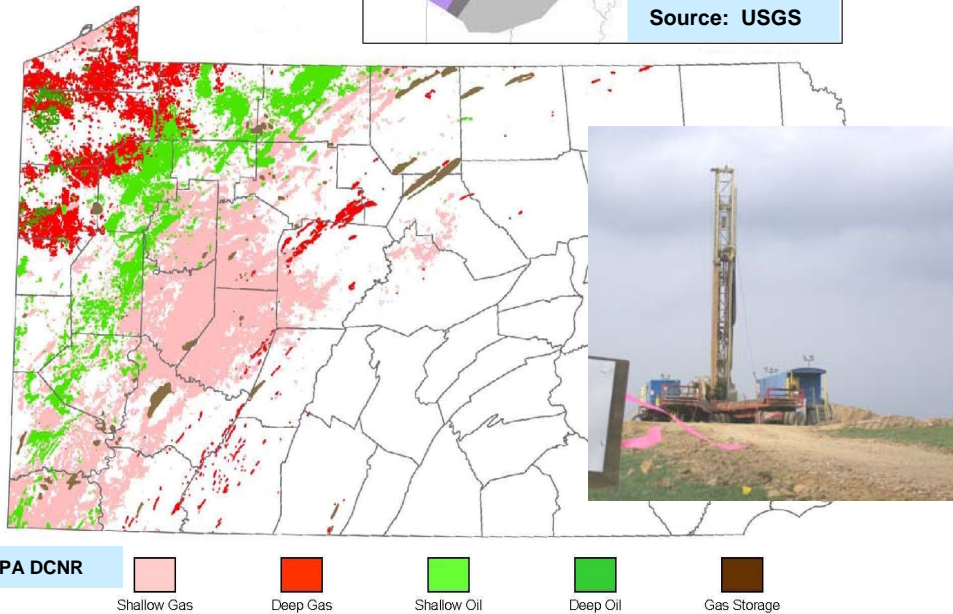
FERC, Staff Report, 2004
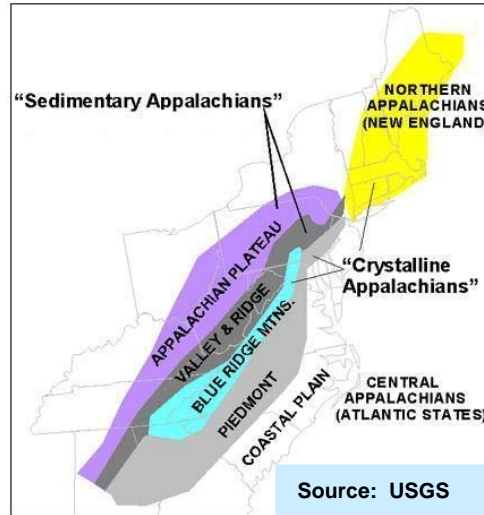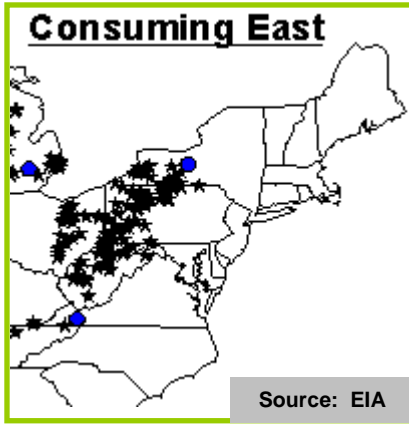
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Background
Depleted Reservoir Natural Gas Storage and Carbon Sequestration
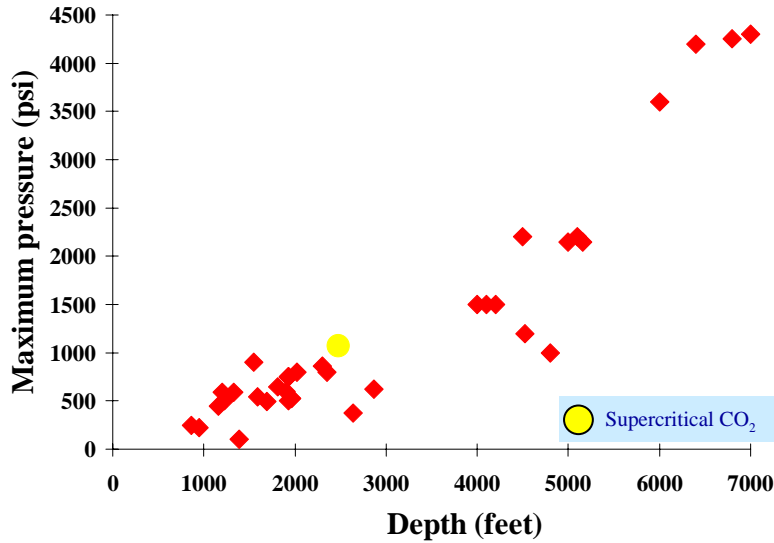

Modified from: USGS
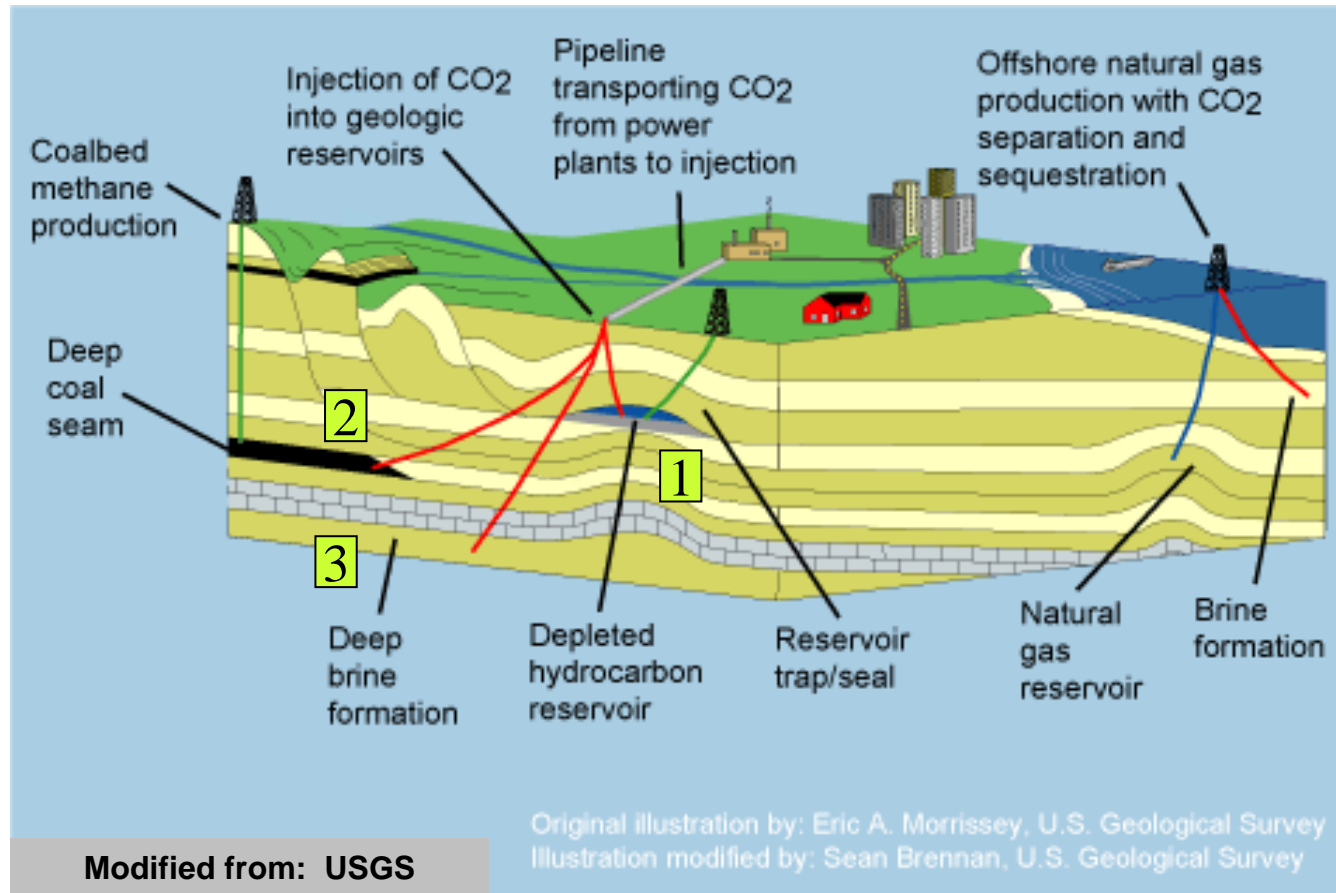
Authorization, siting/design, construction, operations, monitoring, reporting, closure/postclosure

Background - Appalachians

Consuming East
Source: EIA

"Sedimentary Appalachians"
NORTHERN APPALACHIANS (NEW ENGLAND)
APPALACHIAN PLATEAU
VALLEY & RIDGE
BLUE RIDGE MTNS.
PIEDMONT
COASTAL PLAIN
"Crystalline Appalachians"
CENTRAL APPALACHIANS (ATLANTIC STATES)
Source: USGS

SOURCE: PA DCNR
Shallow Gas   Deep Gas   Shallow Oil   Deep Oil   Gas Storage

DEPTH in feet	SYSTEM	ROCK THICKNESS in feet
	PERMIAN	0 - 150
0	PENNSYLVANIAN	350 - 1400
1000	MISSISSIPPIAN	700
2000		
3000		
4000	DEVONIAN	5400
5000		
6000		
7000		
8000	SILURIAN	2400
9000		
10000		
11000	ORDOVICIAN	4000
12000		
13000		
14000	CAMBRIAN	2400
15000		
16000	PRECAMBRIAN ("Basement")	95000 - 135000

EXPLANATION
- Sandstone
- Siltstone & shale
- Black shale
- Coal
- Limestone
- Dolostone
- Salt & other evaporites
- Metamorphic & igneous rocks

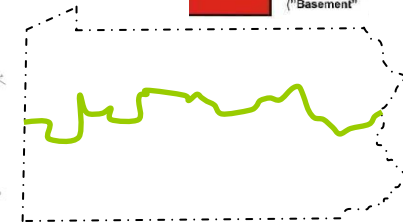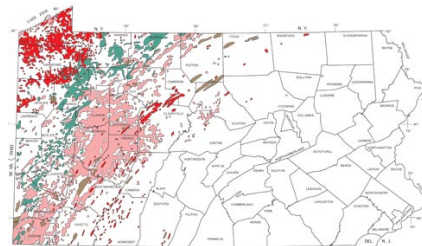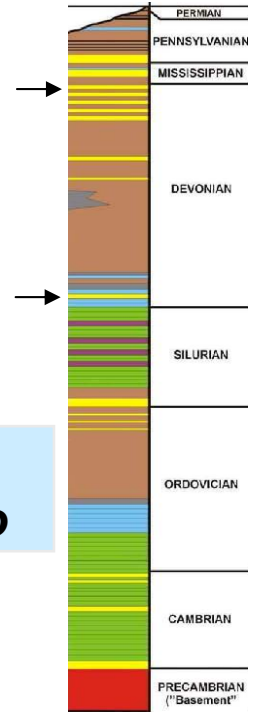SOURCE: PA DCNR

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PA Natural Gas Storage Trends

N. PA reservoir conditions reported
– *Largest TFC, L Devonian Oriskany SS*
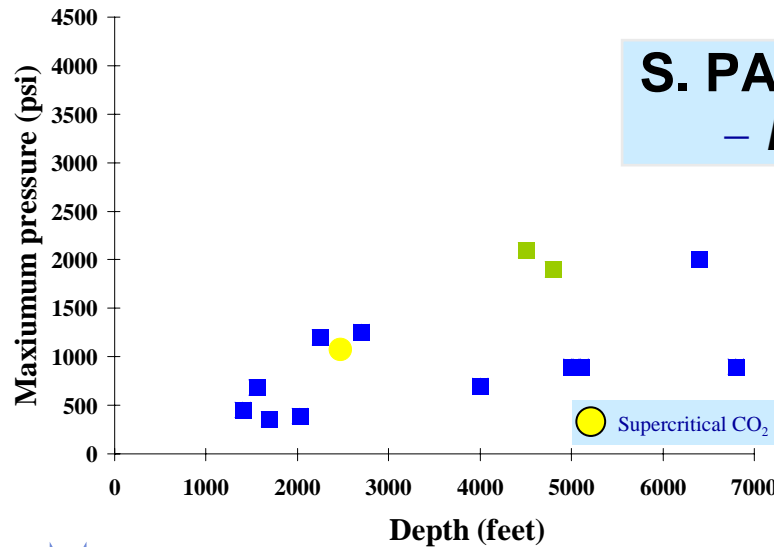
S. PA reservoir conditions reported
– *Largest TFC, U Devonian Venango*

Supercritical CO_2

Supercritical CO_2

Typical Facilities Located in SW PA - East

- **Authorized construction and operations in 1950's**

- **Network of storage and withdrawal wells**

- **Observations wells**

- **Two storage reservoir horizons**

- **Recycling pipeline**

- **Delivery facilities**

- **Compressor stations**

Credit: FERC

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PA Natural Gas Storage Field Trends

| FIELD/CONDITIONS (reported 1998)	SW PA – West	Western PA – Central	SW PA – East
Discovery yr/storage yr	1907/1940	1917/1937	1887/1951
Reservoir type/ trap type	Depleted res./ stratigraphic	Depleted res./ stratigraphic	Depleted res./ structural
Formation age	U. Devonian	U. Devonian	U. Devonian
Reservoir name	Gordon Stray Sand/Venango Gp	1st Sheffield Sand/ Bradford Gp	Fifth sand/Venango Gp (also Murrysville Sand/Berea SS)
Average depth	2,700 ft	2,800 ft	2,250 ft
Average thick.	30 ft	6 - 16 ft	10 - 40 ft
Maximum pressure	1,260 psig	620 psig	1,100 psig
Working gas vol.	5,100 MMcf	900 MMcf	57,001 MMcf
Maximum deliverability	231 MMcfd	20-25 MMcfd	775 MMcfd
No. I/W wells	112	26	228

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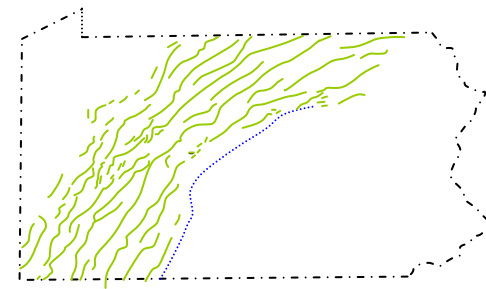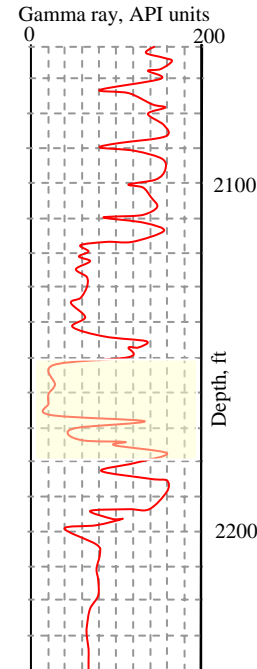
PA Natural Gas Storage Field Trends

SW PA, West

- **Gordon Stray sand, U. Devonian Venango**
- **Fine-med. grained lenticular sand with shale stringers**
- **Porosity: 18-26%; Perm: 40-70 mD**
- **Ave. thickness – 30 ft**
- **Ave. depth – 2,700 ft**
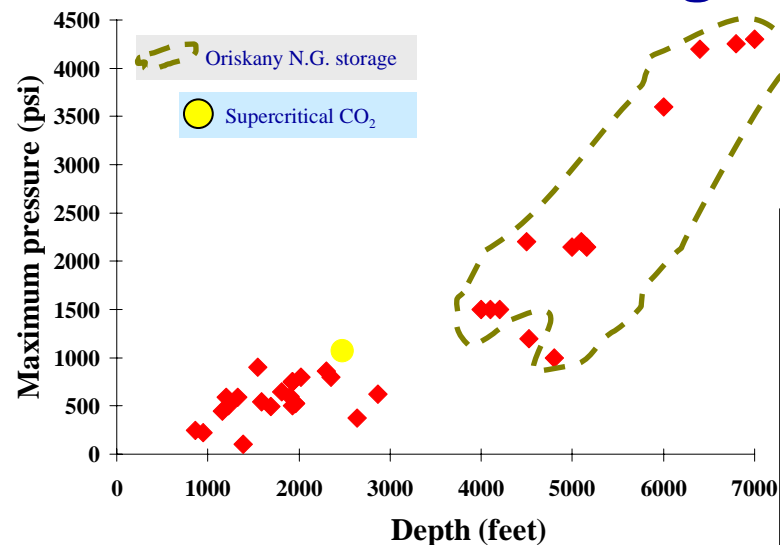- **Max. pressure – 1,260 psig**
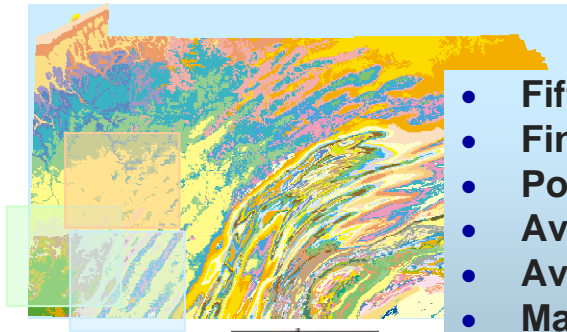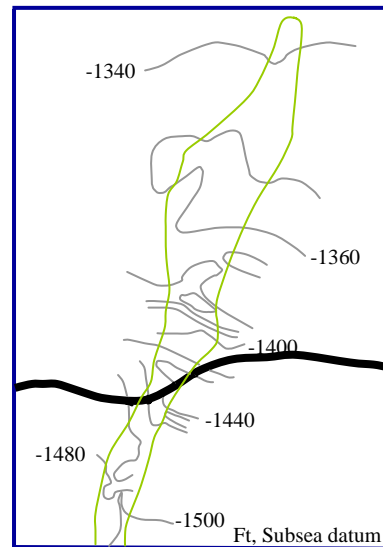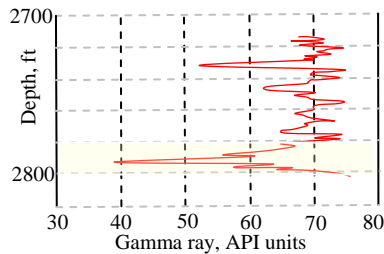
SW PA, East

- **Fifth sand, U. Devonian Venango**
- **Fine-med. grained sand**
- **Porosity: 9%; Perm: up to 1 Darcy**
- **Ave. thickness – 10 - 40 ft**
- **Ave. depth – 2,250 ft**
- **Max. pressure – 1,100 psig**

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SOURCE: DOE DE-AC21-94MC31112

PA Natural Gas Storage Trends – L Devonian Oriskany SS

N. PA reservoir conditions reported
– *Largest TFC, L Devonian Oriskany SS*

Oriskany SS-depth to top

Depth (m)
- 0 - 800
- 800 - 1600
- 1600 - 2400
- 2400 - 3200
- 3200 - 4000
- No Data
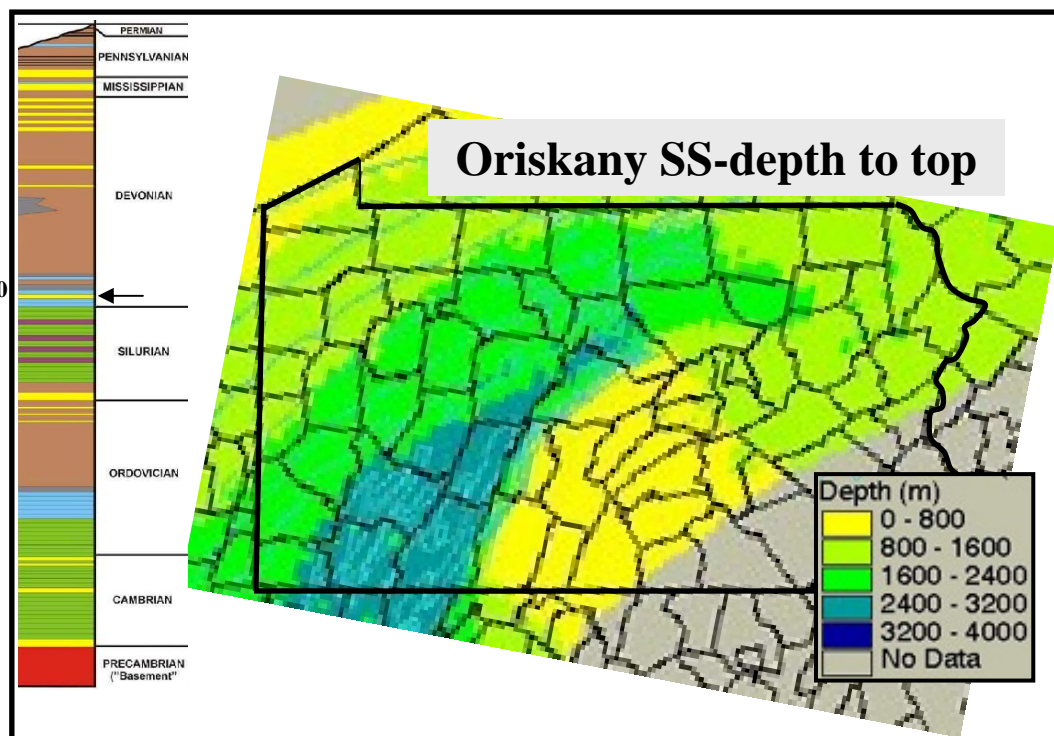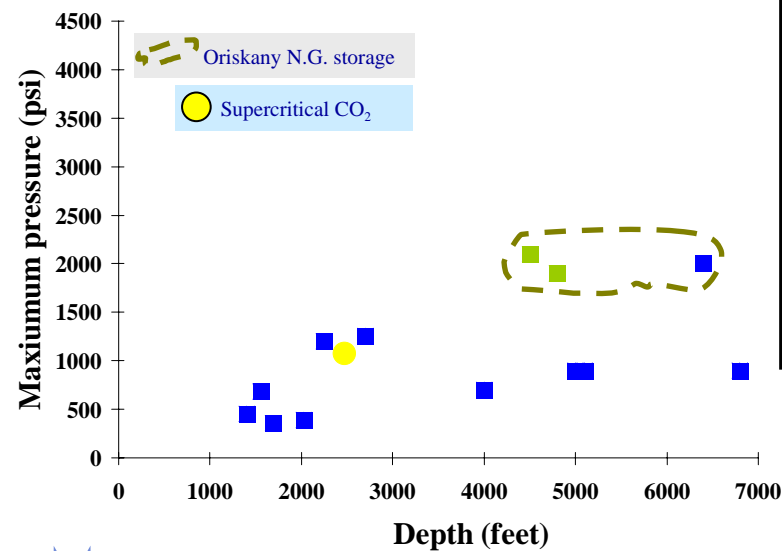
S. PA reservoir conditions reported

Lower Devonian Oriskany Sandstone -
Natural Gas Storage and CCGS Candidate

Pressure (psi)
- 0 - 1000
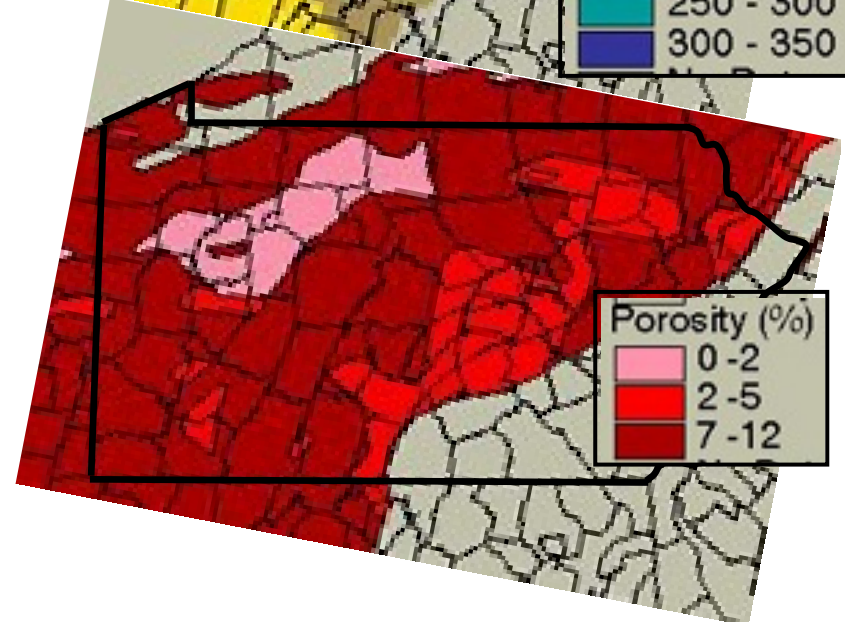- 1000 - 2000
- 2000 - 3000
- 3000 - 4000
- 4000 - 5000
- 5000 - 6000
- No Data

Temperature (C)
- 20 - 50
- 50 - 150
- 150 - 200
- 200 - 250
- 250 - 300
- 300 - 350

Hydraulic conductivity (m/day)
- < .001
- 0.001 -0.042
- .001 - 0.08
- 0.04 -0.3

Porosity (%)
- 0 -2
- 2 -5
- 7 - 12

Source: DOE DE-AC26-98FT40417, Hovorka, et al

Cohen and Trevits, DOE/NIOSH
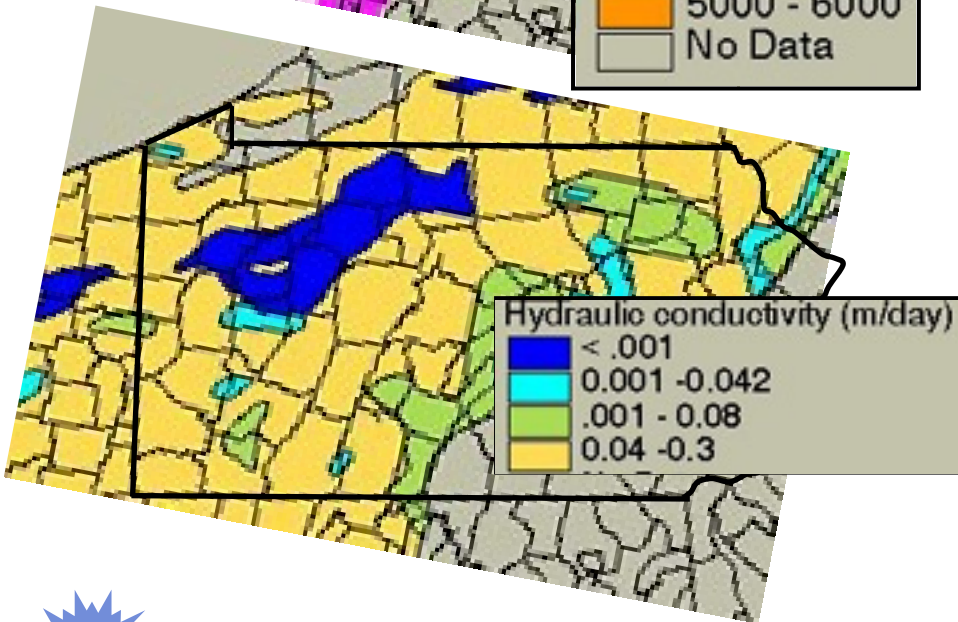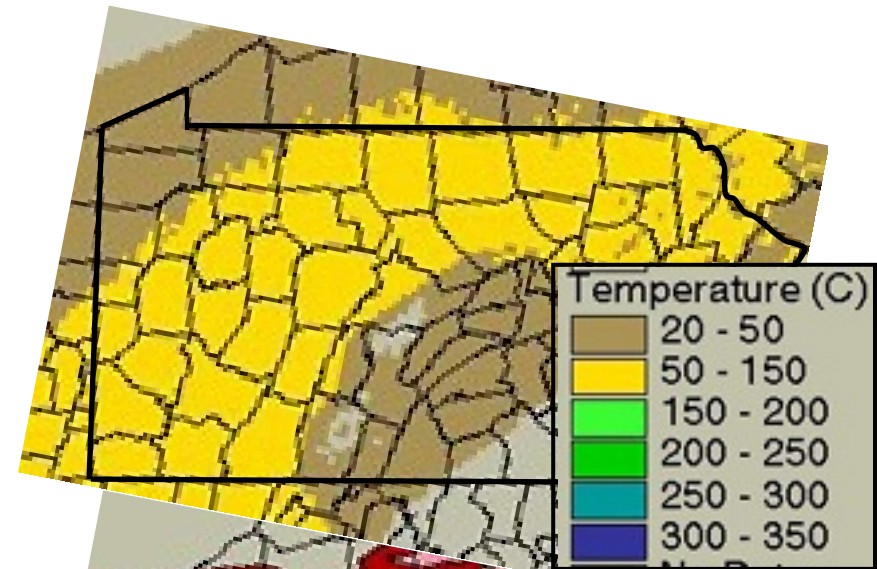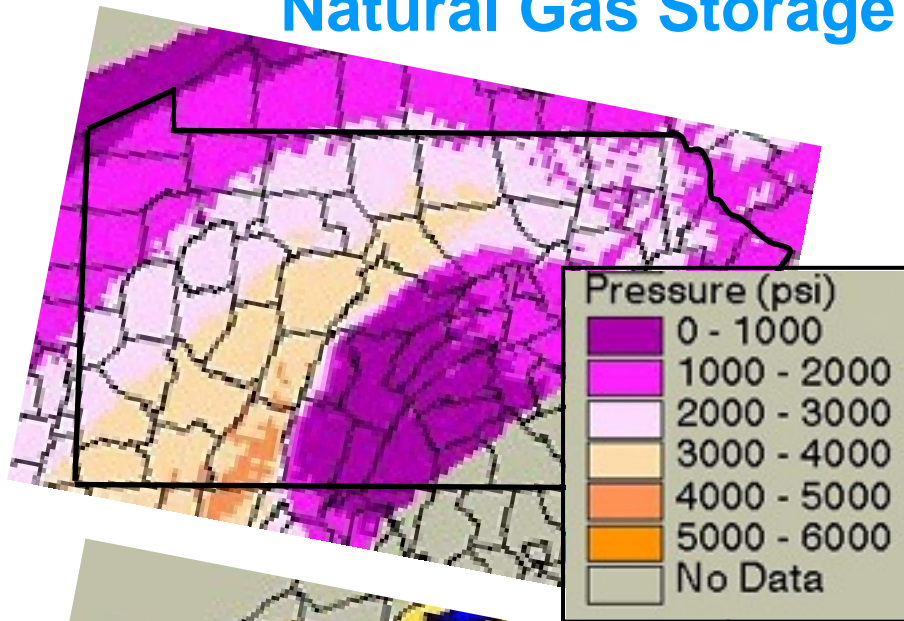
PA Natural Gas Storage Fields – Regulatory

- **Storage well construction**
- **Inspection of storage wells and observation wells**
- **Gas storage well integrity testing**
- **Maximum storage pressure**
- **Emergency repairs**
- **Recordkeeping**
- **Plugging gas storage wells**

PA Natural Gas Storage Fields – Regulatory

- **Required to:**
  - Case and cement gas storage wells to ensure no gas can leak from them
 - Make monthly inspections of all gas storage wells and all wells used for observation
  - Annually inspect the gas storage reservoir and storage protective area to make sure no gas is leaking or other hazardous conditions exists
  - Implement gas storage well monitoring and integrity testing programs once every five years
  - Not exceed pressures that may cause the gas to begin leaking
  - Notify DEP within 24 hours of making emergency repairs to gas storage wells and submit a written explanation of the emergency and what action was taken within five days
  - Keep records of well inspection results and pressure data, integrity testing data, and inspections of abandoned and plugged wells
  - Notify DEP 15 days before the gas storage well is plugged to prevent migration of gas or other fluids within or outside of the well

SOURCE: PA DEP

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Relevance and Synergy

"**5.7.3.2. Engineered Systems**

Evidence from natural gas storage systems enables performance assessments of engineered barriers (wells and associated management and remediation) and of the performance of natural systems that have been altered by pressure cycling…" **IPCC Special Report on Carbon Dioxide Capture and Storage, 2005**
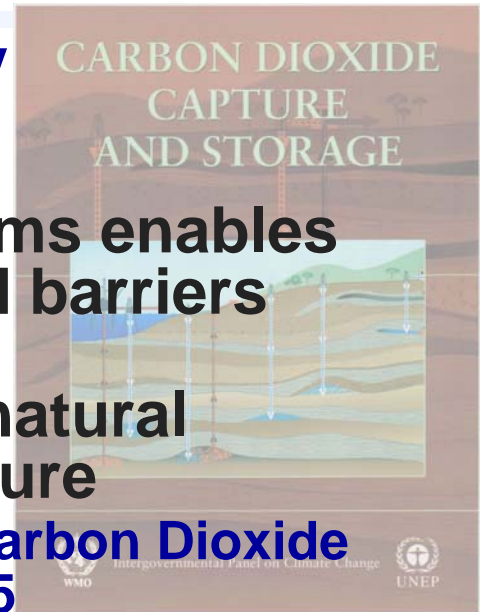
N.G. Storage Observations

- **Proper storage site selection and management is necessary**

- **Injection/withdrawal wells and observation wells required to be properly designed, constructed, monitored, regularly tested, and abandoned**

- **Necessary to avoid overpressure of reservoir**

- **Methane is less corrosive than CO_2 to metallic components**

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Relevance and Synergy

Natural gas storage facilities…
decades of experience and safe operation.

CCGS – progress toward that goal…

EM Transmitter

Source: Carey, LANL

Source: Gasperikova, LBNL/CCP2

CO$_2$SINK
(CSLF endorsed)

Source: UCSanta Cruz/CCP2; Pickles, Jacobson

CCGS Analogues from PA's Natural Gas Storage Fields
Summary

- **Importance and previous studies…**natural gas storage facilities are engineered systems that enable performance assessments of engineered barriers (e.g. wells) and of natural systems altered by pressure cycling

- **Background, PA oil and gas…**depleted reservoirs

- **PA natural gas storage fields – settings, geology, surface/underground facilities, operation, regulatory framework…**decades of experience and safe operations

- **Relevance and synergy for CCGS**

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Next steps and Questions???

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